CHAPTER 7 - STEEL STRUCTURES

SECTION 1. CORROSION

Structural steel is used in most metal waterfront structures because it is strong, readily available, easily fabricated, and not excessively costly. Cast or fabricated steel is normally used for such accessories as bitts, bollards, cleats, and chocks. Other metals have specialized uses because of unique properties, such as being lightweight (e.g., aluminum) or corrosion resistant (e.g., monel).

7.1.1 DEFINITION OF CORROSION. Corrosion is the destruction of a metal by its reaction with the environment. This reaction is an electrochemical oxidation process that usually produces rust or other metal oxide. A more lengthy description of corrosion and the corrosion process can be found in References 7-1 and 7-2.

Since corrosion is an electrochemical process, it requires an electrolyte or current-carrying medium between different parts of the corrosion cell. In marine submerged areas, seawater is the electrolyte; in marine atmospheric areas, salt spray provides the electrolyte. Oxygen greatly accelerates corrosion, which accounts for the rapid corrosion that takes place in the splash-zone area of waterfront structures where both seawater and oxygen are in abundance. Like most spontaneous chemical reactions, corrosion increases with increasing temperature.

7.1.2 TYPES OF MARINE CORROSION. There are many types of marine corrosion that can occur to steel waterfront structures and many methods for corrosion control. In actual practice, these methods are combined in an overall corrosion control program. The most common types of metal corrosion occurring in a marine environment are described in Table 7-1.

SECTION 2. PROTECTIVE COATINGS

7.2.1 PROTECTION. The chief means by which protective coatings impart protection to steel is by providing a barrier between the metal and the environment that is necessary for corrosion to occur. In all cases the coating must be free of pinholes or other discontinuities and of sufficient thickness to prevent the environment from reaching the metal. Certain corrosion inhibitive pigments (e.g., chromate salts and red lead) when properly formulated in a primer pigment can deter corrosion should there be a break in the coating barrier.

Reference 7-3 presents a comprehensive coverage of paints and protective coatings.

Table 7-1. Types of Corrosion

Type	Description	Remarks
Galvanic Corrosion	Two dissimilar metals connected to each other electrically in an electrolyte (e.g., seawater). Current flows through the electrolyte from the more reactive metal (the anode) to the less reactive metal (the cathode), thereby corroding the anode area while protecting the cathode area from corrosion,	1. New steel is anodic to old steel. 2. Brightly cut surfaces (e.g., pipe threads) are anodic to uncut surfaces. 3. Steel is anodic to its surface mill scale. 4. Highly stressed areas (e.g., pipe bends) are anodic to less stressed areas.
Stray Current	Occurs on metal surfaces wherever stray direct current passes from them to an electrolyte. This current most frequently arises from electric railway and crane systems, improperly grounded welding generators, and adjacent cathodic protection systems.	Stray current corrosion should always be suspected as the cause of accelerated corrosion in areas adjacent to sources of DC current and checked for by detection of current flow.
Differential Environmental	Occurs from differences in chemical composition of the medium. Usually results from different levels of aeration (oxygen content); less frequently from different salinities	Corrosion occurs in area of lower oxygen content. On steel piling, this is just below the mean low tide level. Also in crevices and corners because less oxygen is there.
Erosion-Corrosion	Scouring action of sand and other abrasives exposes bright metal and keeps the corrosion active	1. Commonly found at or just above the mud line on steel piling or riser chains of moorings. 2. Wind in sandy areas.
Biological Corrosion	Marine biological organisms accelerate corrosion by changing the normal environment	1. Organisms may create different oxygen levels in the electrolyte. 2. Organisms may create corrosive products through their metabolism or decomposition. 3. Organisms may remove the protective film of corrosion products from metal surfaces.

7.2.2 SURFACE PREPARATION. The proper preparation of steel surfaces prior to coating is essential for maximum coating life and protection of the steel. The selection of the type of surface preparation depends upon the type of paint used, the condition of the surface to be painted, economic considerations, and such practical limitations as time, location, accessibility, and availability of equipment. Standards for surface preparation are found in References 7-4 and 7-5.

Dry abrasive blasting of steel is generally necessary for optimum performance of modern synthetic coatings. It removes mill scale, rust, corrosive salts, and other foreign matter that is detrimental to good coating application and imparts an anchor pattern (tooth) to the steel to which the coating can bond tightly.

Many local air pollution control agencies may restrict dry abrasive blasting because of the dust emitted during operation. The addition of water to the abrasive may be necessary to meet the air pollution control regulations. In such an event, a rust inhibitor needs to be added to the water to prevent rusting before paint application.

Waterblasting of steel without an abrasive may provide a clean surface for re-painting without requiring an abrasive-blast finish. Wire brushing, either manually or with power equipment, can in some cases provide an adequate steel surface for painting.

7.2.3 RECOMMENDED COATINGS. Coal tar coatings are frequently used on steel waterfront structures. Since they are relatively soft, their effectiveness in waters where barnacle fouling is heavy may be limited. Coal tar epoxy coatings are tough, durable, and very impermeable to water; thus, such coatings as Steel Structures Painting Council Paint Specification No. 16 [7-6] have had many years of excellent service. Epoxypolyamide coatings, such as MIL-P-24441, have provided many years of excellent protection to steel waterfront structures, too. Zinc inorganic coatings, such as in Class 3 of MILP-23236, have been used successfully on the atmospheric portions of steel offshore platforms and waterfront structures [7-7]. They must be top-coated with an organic coating for long-term performance in seawater. Vinyl resin paints, such as VR-3 and VR-6 of the Bureau of Reclamation, perform well on steel. Petrolatum-coated tapes [7-8] have been used successfully to protect steel utility lines under piers. They can be applied to wire-brushed as well as abrasive-blasted surfaces. The encapsulation of steel piling with PVC wraps has been reported [7-9] to impart long-term protection from corrosion by producing an oxygen deficient environment.

7.2.4 COATING APPLICATION. In a marine atmosphere, conventional spray, roller, or brush application may be appropriate, as recommended by the coating specification or supplier. A coal tar coating is an economical choice in an atmospheric area where the black color is acceptable.

Application of coatings between tides may be made by spray, roller, or brush, but the coating must be one that will be unaffected by water and will cure under it. Steel Structures Painting Council Paint Specification No. 16 and MIL-P-24441 are two such coatings.

Two different types of coatings are available for application underwater [7-10]. One is a thick putty-like material that is applied by the palm of the hand, and the other is a lower viscosity material that can be applied by brush or roller.

7.2.5 INSPECTION OF COATING. Protective coatings should be inspected at the time of application to make certain that all application requirements have been met. Appendix A of Reference 7-11 is a general guide to inspection of facilities maintenance painting. Visual inspection of coatings before, during, and after application can be effective in detecting deficiencies in the materials, surface preparation, or coating application. If deficiencies in the coating material are suspected, then laboratory testing should be done on paint from unopened cans to verify them. The film thickness of protective coatings is very important because it is directly related to barrier protection. Measurement of both wet and dry film thickness is described in CEL Techdata Sheet 74-11 [7-12].

Coatings on metal surfaces should be checked for holidays, pinholes, or other discontinuities using one of the commercially available holiday detectors. A low-voltage detector (e.g., 50 to 60 volts) is ordinarily used on thin films (i.e., 12 mils or less), and a high-voltage detector (e.g., 10,000 volts) on thicker coatings. The coating must be free of water before the detector is used. Any localized damage to the coating by a high-voltage detector must be repaired.

SECTION 3. CATHODIC PROTECTION

7.3.1 DEFINITION. Cathodic protection is a system for controlling corrosion of a metal surface by passing sufficient direct current onto it to make it a cathode, thus eliminating the possibility of anodic loss of metal. The electrolyte for cathodic protection is usually soil or water. References 7-13 and 7-14 present a detailed description of cathodic protection of buried structures. Thus, discussion of cathodic protection in the present manual will be largely limited to structures in water. In the maintenance of waterfront structures it must be remembered that cathodic protection can prevent corrosion of a new structure or stop corrosion on an existing structure, but it cannot replace metal lost by corrosion of an existing structure.

7.3.2 TYPES OF SYSTEMS. There are two basic systems for supplying the necessary direct current electrical energy to a structure to cause it to become a cathode. The galvanic anode system requires no external power supply, but incorporates anodes of a special alloy that generate the necessary direct current by virtue of a natural voltage difference from the protected structure (Figure 7-1). The galvanic anodes (also known as "sacrificial") are consumed, like the anodes in a typical galvanic corrosion cell, in the process of generating current and, thus, have a limited service life. The galvanic anodes are fabricated from active metals and alloys; three basic materials are used magnesium, zinc, and aluminum of high purity or other special composition.

The impressed current system utilizes low-voltage, high-amperage, direct current from an external power source (Figure 7-2). The positive terminal of the power source must be connected to the anodes, and the

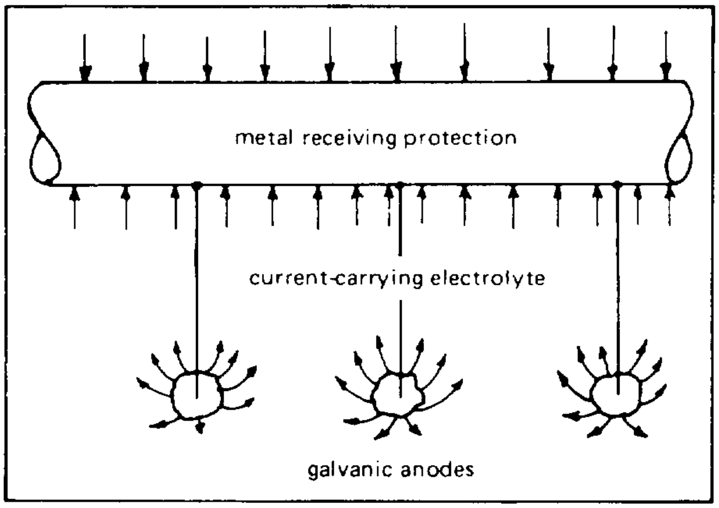

Figure 7-1. Galvanic system of cathodic protection.

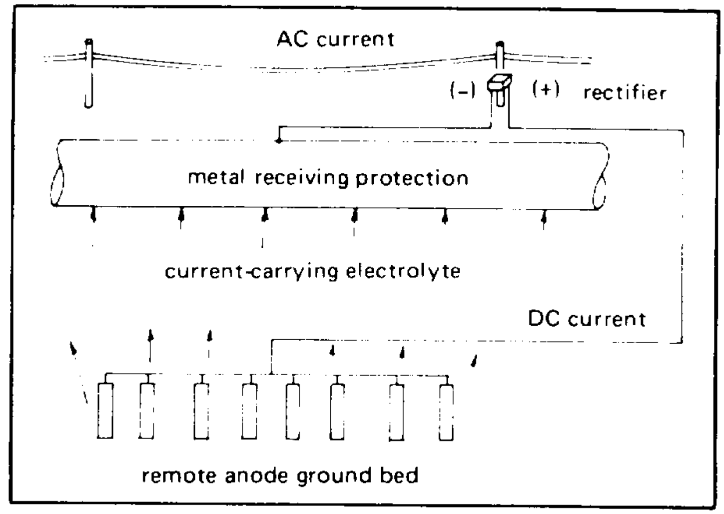

Figure 7-2. Impressed current system of cathodic protection.

negative terminal to the structure to be protected. The relatively stable anodes used to discharge current have much longer service lives than galvanic anodes. These anodes can theoretically he made from any electrically conductive material. However, unless the material is inert in the environment, it will be consumed. Scrap iron, special lead alloys, platinum, platinum-palladium alloy, platinized titanium alloy and platinized tantalum alloy are some of the materials used for the anodes. Normally, rectifiers are used to supply the DC power to the system using available AC shore power. Sections in References 7-1, 7-13, and 7-14 discuss the selection of and requirements for cathodic protection rectifiers.

SECTION 4. SUBSTITUTE MATERIALS FOR STEEL

7.4.1 ALLOYS. There are many alloys which, if used properly, are more resistant to corrosion by seawater and marine atmospheres. These alloys exhibit three types of corrosion behavior. Some are essentially immune to corrosion, while some corrode but at rates significantly slower than steel. Some of these alloys are essentially corrosion free if properly used, but may corrode at extremely rapid rates if used improperly.

7.4.1.1 Titanium Alloys. The titanium alloys are essentially free from corrosion except for stress-corrosion cracking in some alloys. The chemically pure grades and the heat-treatable alloy 6A1-4V annealed (100-ksi yield) are known to be immune to all forms of attack in seawater and marine atmospheres at temperatures below 1500F. These alloys are high in cost and difficult to fabricate. They are, however, relatively high in strength and low in weight.

7.4.1.2 Nickel Alloys. Nickel alloys, depending on their composition, can exhibit either totally immune behavior or can be essentially immune when used properly. Inconel alloy 625 and Hastelloy alloy C are essentially immune to corrosion in marine environments.

Monel alloy 400 normally exhibits immune behavior when it receives cathodic protection from a more active material. (See MO-306, [7-1]). If the area ratio is favorable (small area of monel/large area of anodic material), the amount of acceleration of corrosion of the anodic material will be insignificant. However, if it is not cathodically protected, this alloy will corrode due to pitting and crevice attack.

7.4.1.3 Copper Alloys. Many of the copper alloys corrode uniformly at low rates when exposed to marine environments in low velocity water movement. These alloys include copper, cupro-nickel 90-10, cupronickel 70-30, arsenical admiralty brass, and most true bronzes. Most of the true brasses are generally attacked by dezincification and are unsuitable for marine applications.

7.4.1.4 Aluminum Alloys. The aluminum alloys are subject to pitting and crevice corrosion in marine environments. This is particularly true in submerged structures. If pitting can be tolerated (for instance, in an open framework structure) and if crevices can be eliminated (by using welded structures), the aluminum alloys can be successfully used in marine applications where their low weight or other unique properties would be utilized. They should not, in general, be substituted for steel on the sole basis of corrosion resistance. Of the aluminum alloys the 5000 series (5083 and 5086) and the 6000 series (6061) alloys have the best corrosion resistance. Alloys in the 2000 series, 3000 series, and 7000 series are less corrosion resistant.

7.4.1.5 Stainless Steels. It cannot be overemphasized that stainless steels can and do corrode in seawater. The stainless steels can be essentially immune to corrosion in marine environments when they are properly used. However, they corrode very rapidly in marine environments when improperly used. The predominant mode of corrosion of the "marine grades" of stainless steels the 300 series is crevice corrosion. If crevices are avoided or if they are cathodically protected (possibly by galvanic coupling), these alloys can be essentially corrosion free. However, rapid failure from corrosion in existing crevices will result when the alloys do not receive cathodic protection. Stainless steel grades 304 and 316 are the most widely used "marine grade" stainless steels. Grades 303 and other series, such as the 400 series, should be avoided. Alloy 30-Cb has somewhat greater corrosion resistance than grade 316, but it is susceptible to crevice corrosion.

7.4.2 PLASTICS. There are a number of plastic or elastomeric materials that find uses as components of waterfront structures rather than metals. Fiberglass-reinforced plastic landing floats, brows, and mooring buoys have been prepared by using spray-up or lay-up construction techniques [7-15]. With proper design they can be quite rugged and require very little maintenance. Such construction techniques can also be used for applying a tough protective coating to steel structures, such as buoys.

Urethane, polystyrene, and syntactic foams are available in a variety of densities and forms for imparting buoyancy to floating structures. Urethane has a greater capability than the others, in that it is easily foamed in place [7-16]. For more information see Chapter 8 of this manual.

7.4.3 RUBBER. A number of hollow and solid rubber products are available for use as fenders on piers, wharves, landing floats, camels, and mooring buoys.

SECTION 5. INSPECTION

7.5.1 GENERAL CONSIDERATIONS. Because of rapid corrosion, continuous inspection is a basic requirement of the maintenance program for steel waterfront structures. An inspection program identifies all deficiencies and degree of hazard and determines proper corrective action.

7.5.2 INSPECTION TECHNIQUES

7.5.2.1 Visual Inspection. It is vital that the actual metal surface be inspected where deterioration is proceeding. Marine fouling, dirt, loose paint, or corrosion products will interfere with an accurate assessment of the extent of deterioration and so must be removed before inspection. Of course, coatings which are supplying protection to the surface and are not defective should not be removed for inspection. Visual inspections can be used to determine the location and relative extent of corrosion on many structures. Measurement of metal thickness by gages, etc., can, in many cases, give accurate and quantitative determinations of the extent of corrosion. Careful visual examination can also be used to determine the cause of the corrosion.

When structures are below water and are difficult or impossible to bring above water, a diver can be used to perform the inspection. He must be able to obtain and report information on the condition of the underwater structures (see Appendix A). The limitations of the divers senses underwater must be considered when evaluating the information obtained from an underwater inspection.

7.5.2.2 Cutting of Metal for Thickness Measurement. When normal caliper-type measurement of metal thickness is not possible, holes can often be cut in the members to determine material thickness. This can be performed only when the presence of a small hole can be tolerated or the hole can be patched.

7.5.2.3 Ultrasonic Testing. Ultrasonic testing can be used both to determine metal thickness and to detect internal flaws. Instruments are now available that directly indicate metal thickness. These instruments are well-suited to general determinations of metal thickness and only require access to one side of the member. These instruments can be used in the field with a minimum of operator training. Instruments for location of internal flaws are also available. However, the operation of these instruments and the interpretation of the test results are heavily dependent on the skill and experience of the operator. Both types of these devices could be adapted for underwater use.

7.5.2.4 Radiography. Radiography (X-ray) can be used to determine variation in metal thickness and detect certain types of internal flaws (voids and inclusions).

Radiography has the advantage of producing a record (film) that can be viewed and interpreted at a later date. Also, radiography can often be used to penetrate coatings, etc., which interfere with many other inspection techniques.

7.5.2.5 Microscopic Testing. Microscopic inspection of the internal structure of a material is most often performed in a material testing laboratory on samples removed from a structure. While this form of inspection can determine the extent of deterioration, it is most often used to determine the form of attack. Often the form of attack must be determined in order to find the cause of attack and recommend corrective action.

7.5.2.6 Examination of Corrosion Products. Chemical analysis of corrosion products is, like microscopic testing, most often performed in a laboratory on samples removed from a structure. The composition of the corrosion products is normally useful in the determination of the cause of attack, not the extent of attack.

7.5.2.7 Potential Measurements on Cathodically Protected Structures. The extent of protection can be determined by measuring the electrical potential of a cathodically protected buried or submerged structure. Techniques for determination of these potentials are outlined in References 1-4 and 7-1. Criteria for evaluation of these potentials are given in References 7-13 and 7-14.

7.5.3 SPECIFIC STRUCTURES

7.5.3.1 Piling. Pipe, H, and sheet piling (including tie rods) should be inspected for extent of corrosion, metal thickness, condition of coating, and level of cathodic protection (where appropriate). It may be necessary to remove fouling by scraping to expose immersed metal surfaces. Mechanical damage and structural integrity must be determined (Figure 7-3). Soil subsidence behind sheet piling is evidence that holes in the piling exist (Figure 7-4). An outward displacement of a quaywall or steel piling is evidence that broken tie rods exist. Divers and boats are both appropriate methods for inspecting piles.

7.5.3.2 Floating Pontoon Structures. Floating pontoon structures are sometimes used as landing floats, lifts, camels, etc. They should be inspected for seaworthiness, corrosion below water which would lead to sinking, and condition of fendering. Nonskid matting may be of advantage on slippery surfaces.

7.5.3.3 Supporting Components. Structural components above the water and below the deck (e.g., wales, braces, etc.) are best inspected from a boat. The extent of corrosion, metal thickness, mechanical damage, and condition of coating should be noted.

7.5.3.4 Utility Lines. Utility distribution systems (Figure 7-5) should be inspected at least annually and possibly more frequently as necessary, depending on the particular installation and type of service given. The following paragraphs define the utility distribution systems, and Table 7-2 presents a few inspection checkpoints that are adequate for average installations. Further detailed procedures for the inspection of utility distribution systems are given in the appropriate references of each service. The preventive maintenance inspector should report breakdowns immediately to the cognizant supervisor. Records of all inspections of utility distribution systems should be maintained.

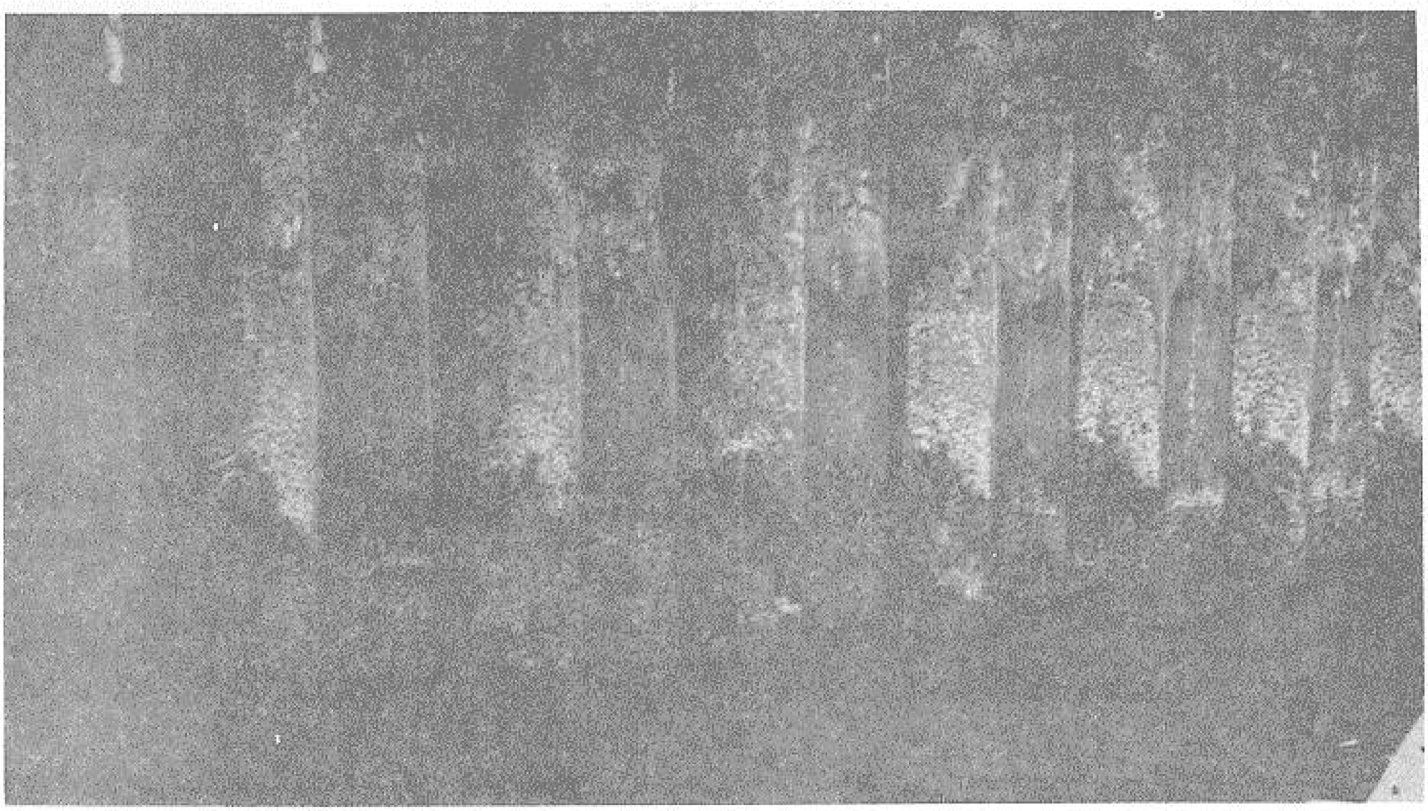

Figure 7-3. *Typical example of corrosion damage to sheet piling.*

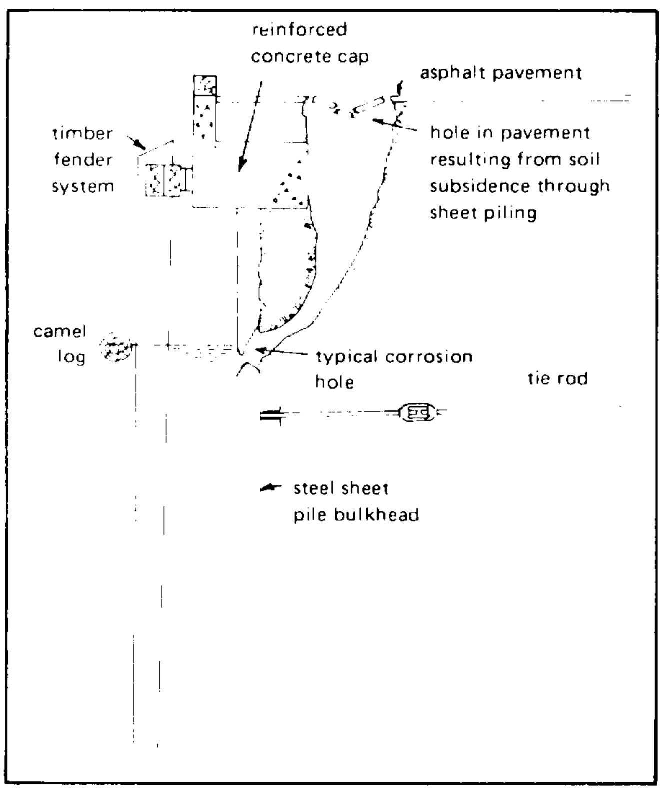

Figure 7-4. Hole in sheet piling causing soil subsidence.

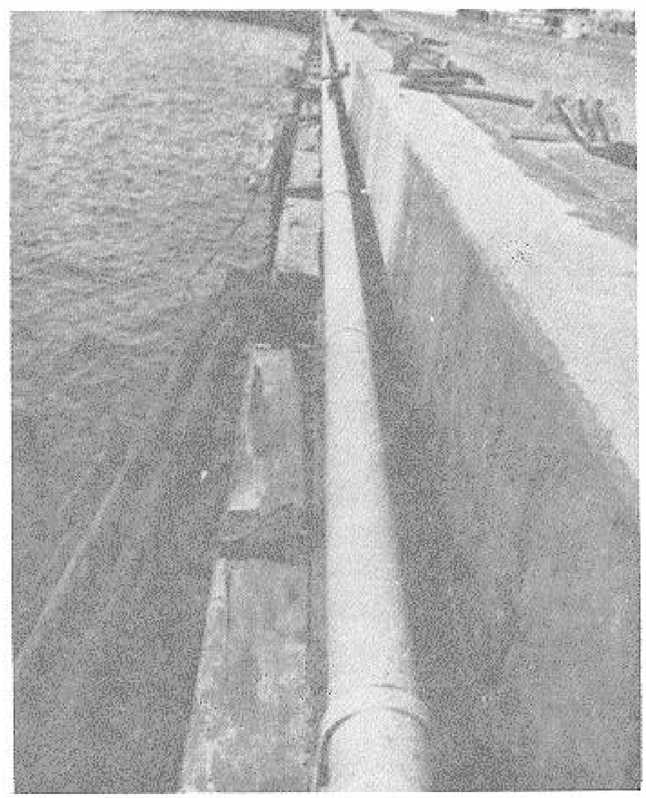

Figure 7-5. Example of utility line properly emplaced.

Table 7-2. Inspection Checkpoints for Utility Distribution Systems

Type of Line	**Inspection Checkpoints**
Steam distribution and condensate return systems; hot water distribution system	Monthly: 1. Pipes for leakage; damage to insulation; abnormal pressures and temperatures; abnormal pressure drops; vibration. 2. Anchors, hangers, and supports for corrosion, breakage, or cracks. pressure and temperature controllers, strainers, and auxiliaries. Yearly: 1. Pipes for corrosion, leakage, and loose joints; condition of insulation; damaged protective jackets. 2. Poles, hangers, or other supporting members for settling or shifting of position. 3. Condition of anchor, hangers, guides, and supports. 4. Valves for leakage or corrosion; defects in stems, handwheels, flanges and gaskets. 5. Settings of relief and safety valves. 6. Condition and calibration of pressure-reducing stations. 7. Signs of corrosion on condensate return pipings. 8. Fittings for tightness, threads in good condition.
Water distribution systems [potable (freshwater), salt water or fire protection, and chilled water]	Yearly: 1. Pipes for leakage, corrosion, loose connections; defective caulked joints on bell-and-spigot pipes; loose bolts on flanged pipe; damaged or missing hanger and supports; mechanical damage; rust, corrosion, scaling, peeling, alligatoring, or damage to protective coatings; excessive supply pressure, water hammer, or vibratory noise in line. 2. Valves for leakage, rust, corrosion; visible defects in stem, handwheel, body, packing gland, flanges, and gaskets; difficulty of operation, condition, or damage to protective coatings. 3. Shore-to-ship pier connection fittings shall be removed to insure threads are safe. 4. Meters for leakage, corrosion, broken glasses; evidence of faulty operation.

continued

Table 7-2. Continued.

Type of Line	Inspection Checkpoints
Sewage collection systems	Yearly: 1. Pipes for leakage, rust, corrosion, and deteriorated coating; clogging, sluggish flow. 2. Check for loose, missing, or broken supports and anchors, and other damage.
Gas distribution systems	Yearly: 1. Pipes for leakage, loose connections, rust, corrosion, and other damage. 2. Condition of anchors, hangers, and supports. 3. Location of piping (should never be installed under a building). 4. Guardrails protecting aboveground piping that is near a street or is vulnerable to damage by vehicular traffic; piping appropriately painted. 5. Leaks accurately marked with tags to show classification of leak. 6. Valves for leakage, loose connections, rust, corrosion; defective operation. 7. Connections for leaks. 8. Meters for loose connections, leakage, corrosion, rust, broken glass, defective gaskets, dirt, or illegibility.
Compressed air distribution systems	Monthly: 1. Leaks (very important); moisture and dirt in traps, strainers, and dehumidifiers. 2. Abnormal pressures. 3. Vibration. 4. Corrosion. Yearly: 1. Pipes for leakage, corrosion, loose joints, damaged, or missing supports. 2. Settling or shifting of poles, hangers, or other supporting members. 3. Valves for leakage and corrosion; defects in stems, packing glands, handwheels, seats, bodies, flanges, and gaskets. 4. Condition of flanged fittings, expansion joints, hangers, guides, supports, and anchors.

continued

Table 7-2. Continued.

Type of Line	Inspection Checkpoints
	5. Condition of traps, strainers, dehumidifiers, and moisture separators. 6. Condition and calibration of instruments.
Electric power transmission and distribution systems	Yearly: 1. Conduits and supports for corrosion; missing or unsecured covers and fittings; plugged drain openings; accumulations of dirt and debris in ducts and wireways; missing fasteners; overcrowding of conductors in conduits, ducts, wireways, and racks; unidentified wires. 2. Insulations for abrasion; broken insulation; defective insulation at splices; inadequate or loose tape, overheated or burned insulation; rodent- or insect-damaged insulation. 3. Conductors exposed to pedestrian or vehicular traffic. 4. Exposure to water, grease, and oil. 5. Receptacle outlets, panels, and miscellaneous fittings protected against foul weather and entrance of dirt and moisture; dirty or corroded contacts; hotspots, burning, and arcing; loose fittings; defective grounding; missing, illegible, incorrect, or inadequate indexing, instructions, or phase and polarity markings; missing or loose covers of outlet boxes, receptacles, and terminal boxes; corrosion of exposed metal surfaces; overloaded circuits; and visibility of fire alarm boxes. 6. Pier lighting and flood lights for dirt, rust, corrosion, loose connections, charred insulation, arcing, and illumination level.
Petroleum fuel distribution systems	Yearly: 1. Piping for leakage and loose connections; damaged or missing hangers and supports; misalignment causing undue stresses at pipe joints; defective gland nuts and bolts at expansion joints and clamp-type couplings; rust, corrosion, cracking, scaling, peeling or damaged paint or protective covering; failure to maintain electrical continuity for grounding connections; inaccurate, illegible, and improper paint color for signs and markings. 2. Valves for leakage and corrosion; visible defects in stem, operating handwheel or lever, packing gland, flanges, and

continued

Table 7-2. Continued.

Type of Line	Inspection Checkpoints
	gaskets; wear, mechanical damage, or difficult operation; damage to protective coating; identify cast iron valves for future replacement. 3. Meters, pressure gages, and other accessories for leakage; cracked dial cover glasses; defective gaskets; mechanical damage or inaccuracy of indicating and recording mechanisms; rust, corrosion, broken weld; loose, missing, or damaged parts; unsafe conditions; deteriorated parts of ladders or catwalks. 4. Assure fuel connections are inboard of pier edge; concrete curbs or metal drip pans are provided around fuel risers and connections; plugs are provided for openings in curbs or pier decks.
Telephone wire systems and fire alarm systems	Yearly: 1. Defective faceplate; dirt. 2. Loose wire connections, crosses, or shorts. 3. Corroded, deteriorated, or damaged wires. 4. Adequate clearance from trees, electric light and power wires, or buildings. 5. Condition of protector. 6. Kinks; cut in cable; creeping cable; loose or misplaced cable guards and supports. 7. Defective insulation; improperly terminated wires. 8. Debris hanging on wires. 9. Nonuniform, excessive, or insufficient sagging. 10. Proper grounding.
Shore-to-ship utility lines	Prior to each use and after connection: 1. All portable lines for Cold Iron (Hotel Service) examined for mechanical damage and abrasion. 2. Electrical distribution lines checked for equal length prior to connection and for overheating after service established. 3. All hoses checked for leakage and excessive stress after placement.

7.5.3.4.1 Steam Distribution and Condensate Return Systems. Steam distribution and condensate return systems are defined as the piping between the point of supply to the point of steam use. The basic components of the systems normally located at waterfront facilities include: steam and condensate piping, expansion joints and loops, pipe anchors, valves, insulation and covering, conduit, and structural supports. Jackets in seawater should be checked for watertightness. See Table 7-2 for inspection checkpoints.

7.5.3.4.2 Hotwater Distribution Systems. Hotwater distribution systems are defined as piping in which water is circulated between the source and the point of hotwater use. The basic components of the hotwater systems normally found at waterfront facilities are: pipes, valves, expansion joints and anchors, and drains and vents. See Table 7-2 for inspection checkpoints.

7.5.3.4.3 Water Distribution Systems. Water distribution systems are defined as all water conduits and supply mains, with necessary appurtenances, through which water is conducted between the source and the point of utilization. Nonpotable water systems for fire protection and sanitary purposes are included. The basic components of systems normally found at waterfront facilities are: conduits, supply mains and service lines, valves, manholes, hydrants, meter and equipment for measurements and control, and all appurtenant equipment, such as automatic controls and cathodic protection devices. See Table 7-2 for inspection checkpoints.

7.5.3.4.4 Sewage Collection Systems. Sewage collection systems are defined as all conduits, sewers, and appurtenances through which domestic sewage or industrial wastes are collected and transported between the point Of origin and the point of discharge. Pumping stations are not included. The basic components of sewage collection systems normally found at waterfront facilities are: force mains, main sewers and laterals, and small individual disposal devices, such as septic tanks.

7.5.3.4.5 Gas Distribution Systems. Gas distribution systems are defined as all government-owned gas piping between the source and point of gas use. The basic components of gas distribution systems are: piping, valves, expansion joints, anchors, drains, meters, pressure regulators, and cathodic protection. Gas distribution systems are seldom found under piers or wharves; however, if one is already installed, the checkpoints given in Table 7-2 should be followed.

7.5.3.4.6 Compressed Air Distribution Systems. Compressed air distribution systems are defined as the compressed air piping between the compressor room and the point of use. The basic components of compressed air distribution systems are piping, valves, expansion joints, anchors, drains, and pressure regulators. See Table 7-2 for monthly and yearly inspection checkpoints.

7.5.3.4.7 Electric Power Transmission and Distribution Systems. Electric power transmission and distribution systems are defined as (1) overhead and underground transmission and distribution lines from generating stations, or delivery point to all main service entrance switches in a building; (2) exterior lighting systems, including street lighting, flood lighting, perimenter lighting, and security lighting; and (3) fire alarms systems.

The inspection procedure should comply with all current safety precautions, remembering that shock hazards are intensified in the waterfront environment. See Table 7-2 for inspection checkpoints.

7.5.3.4.8 Petroleum Fuel Distribution Systems. Petroleum fuel distribution systems are defined as piping systems in which petroleum fuel is received from a transporting vessel or discharged from storage. The basic components of the systems include piping, valves, control equipment, ground connections, signs, and markings. Motor vehicle fill stands, drum-filling plants, or storage tanks are not included.

Early detection of corrosion attack upon the various fuel facility components constitutes one of the most important phases of inspection (see Reference 7-17). A record of all inspections of fuel systems should be maintained. See Table 7-2 for inspection checkpoints.

7.5.3.4.9 Telephone Wire Systems. Telephone wire systems are defined as wire communication systems which convey intelligibility from speaker to the listener. The basic components of the systems normally located at waterfront facilities are receiver, transmission lines, connecting boxes, and cable terminals.

The inspection procedure should comply with all current safety precautions. See Table 7-2 for inspection checkpoints.

7.5.3.5 Mooring Fittings. Bollards, bitts, cleats, chocks, rings, and other steel mooring fittings must be inspected for extent of deterioration to determine if the fittings, holddown bolts, or foundations need repair or replacement (Figure 7-6). Necessary requirements for painting or refilling of boltholes should be determined.

7.5.3.6 Drydocks (Graving Docks, Marine Railways, and Lifts). Drydocking facilities must be maintained to the extent necessary to protect and preserve the structure and all operating equipment to assure full, safe, and efficient use of the facilities at all times. See Appendix B for more information on inspection of graving docks.

7.5.3.7 Floating Structures. Steel pontoons, landing floats, barges, floating cranes, floating caissons (graving dock entrance closures), and miscellaneous floating structures must be inspected regularly for structural damage, water-tightness, corrosion, condition of coating, and where appropriate, extent of marine fouling. If marine fouling organisms are significantly reducing the buoyancy or increasing the drag of moving equipment, they must be removed by in-place cleaning or by cleaning after drydocking.

SECTION 6. MAINTENANCE OF STEEL STRUCTURES

7.6.1 STRUCTURAL CONSIDERATIONS. Structural engineers should be consulted to ensure that the repair method will restore the steel structures to the desired strength and that the most effective method of repair has been chosen. Load-carrying members are usually replaced when 30% or more of the steel has been lost by

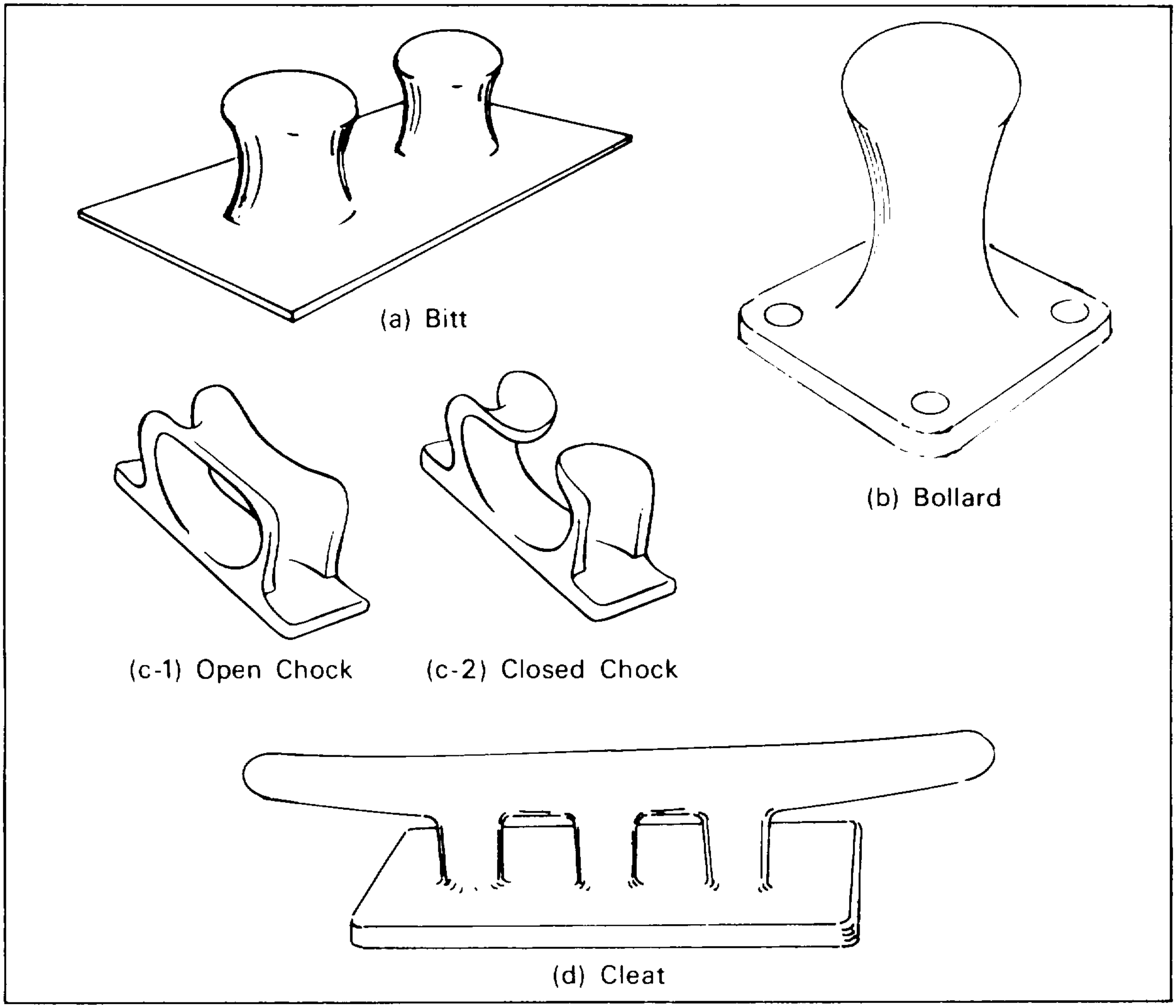

Figure 7-6. Examples of mooring fittings.

corrosion or when they are deformed. If adjacent members show signs of serious deterioration, it may be more economical to replace whole frames or bents. A stressed member should not be removed before the stress has been relieved by transfer of load to adjoining members or by new temporary members and adequate bracing. In the replacing of piles, the load should be shifted temporarily to other piles by struts or beams using jacks. The replacement of wales on quaywalls may require excavation of fill to relieve lateral loads. In some cases, it may be more economical or practical to strengthen existing members than to replace them. This is especially true where corrosion is serious in only a limited area.

7.6.2 PILING. Steel piling requiring coating should be treated as described in 7.2. Those requiring cathodic protection should be treated as described in 7.3. The cathodic protection systems themselves must be inspected for depleted anodes, corroded or loose connections, electrical continuity, etc., and maintained on a yearly basis to assure continuous protection of the steel.

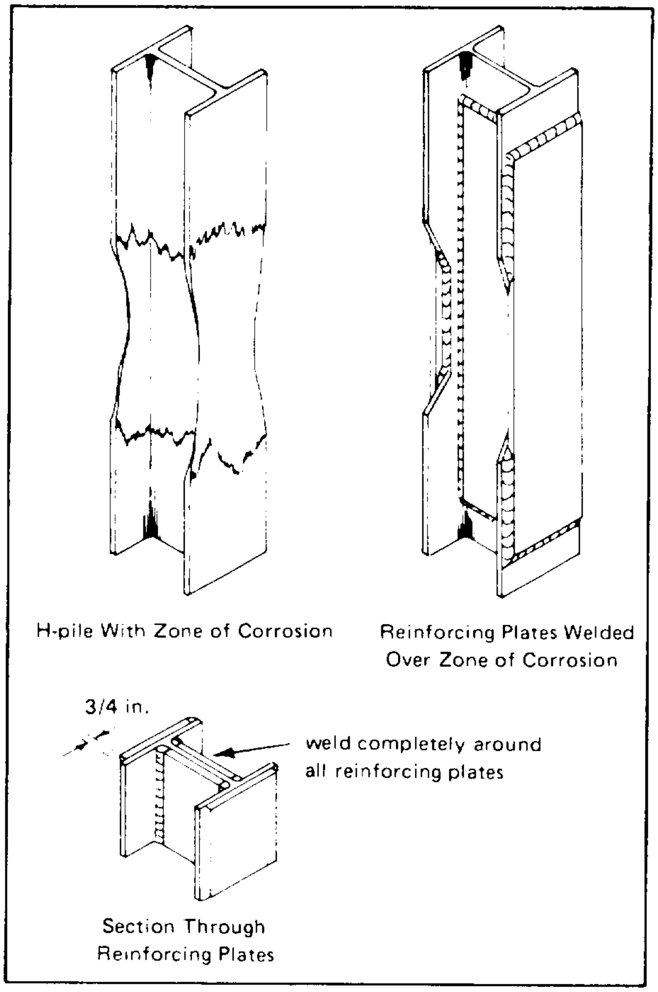

Figure 7-7. Repair of corroded steel pile.

7.6.2.1 H-Piling. Reinforcement of H-piling by welding steel plates onto flanges and web may be appropriate in localized areas of corrosion, such as the tidal zone. The reinforcing plates should be of sufficient thickness to restore the original strength to the piling and of sufficient area to encompass and extend beyond the extremities of the corroded area (Figure 7-7). The old steel must be cleaned and cut back to a point where the metal thickness will ensure a strong weld. All cut edges should be feathered, and the weld should be made completely around the plate to eliminate crevices.

Another method of reinforcement utilizes encapsulation in reinforced concrete. In this method, reinforcing rods are welded along the main axis of the repaired member, across the damaged area. Ties are welded or tied at all intersections with reinforcing steel, a form is placed around the piling, and concrete is placed inside as described in Chapter 3. When replacement is necessary, the new piling must be accurately fabricated to match the old, making sure that bolt and rivet holes are properly located. When replacing bearing piling, the new pile is generally driven alongside the old one at a slight angle. It is then cut off at the proper elevation, capped (usually by welding on a steel plate), and pulled into position with a block and tackle. If the old pile is removed before the new one is driven, the load must be temporarily transferred until the new pile can assume it.

7.6.2.2 Sheet Piling. Sheet piling usually serve as a bulkhead to retain fill. Thus, extreme care must be taken during replacement of one or more piles to prevent failure and passage of fill through the opened spaces into the water. More frequently, small holes are patched by welding steel plates over them, and badly deteriorated piling are generally replaced or protected by having new piles driven in front of them. In the latter case new wales, tie rods, and deadmen should be installed, and the space between the old and new piles should be filled with well-tamped earth, sand, gravel, or concrete.

An alternate method of repairing badly deteriorated piling is to install a concrete facing. The old steel must be cleaned of rust, marine fouling, and other contaminants before a concrete cover of at least 6-inch thickness is installed. A bolted wooden form is generally used for this purpose. When the back of the bulkhead is accessible, the entire steel bulkhead can be encased in concrete with a minimum thickness of 3 inches on each side (Figure 7-8). Whenever backfill is replaced, it should be added in layers (preferably granular material) and be well compacted. To replace deteriorated tie rods, a trench is dug from the sheet piling to the deadman, and the new rods with new turnbuckles are installed one at a time (Figure 7-9). They should be covered with a bituminous coating, a fabric tape, and a final bituminous coating. The deadman should be inspected, and necessary repairs made before the trench is backfilled.

7.6.2.3 Pipe Piling. Pipe piling repair is generally similar to that of H-piling repair.

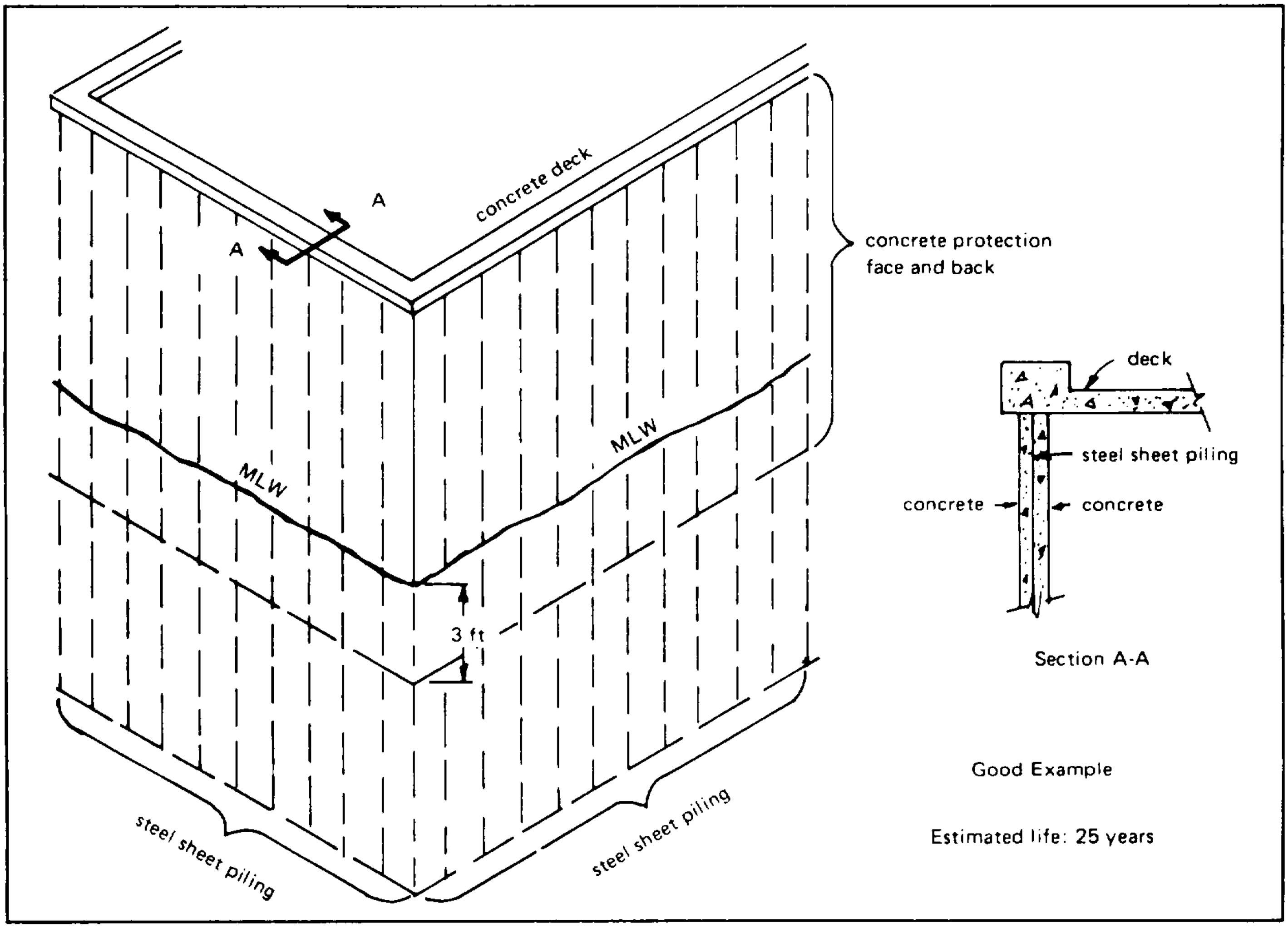

Figure 7-8. Concrete-protected steel sheet piling.

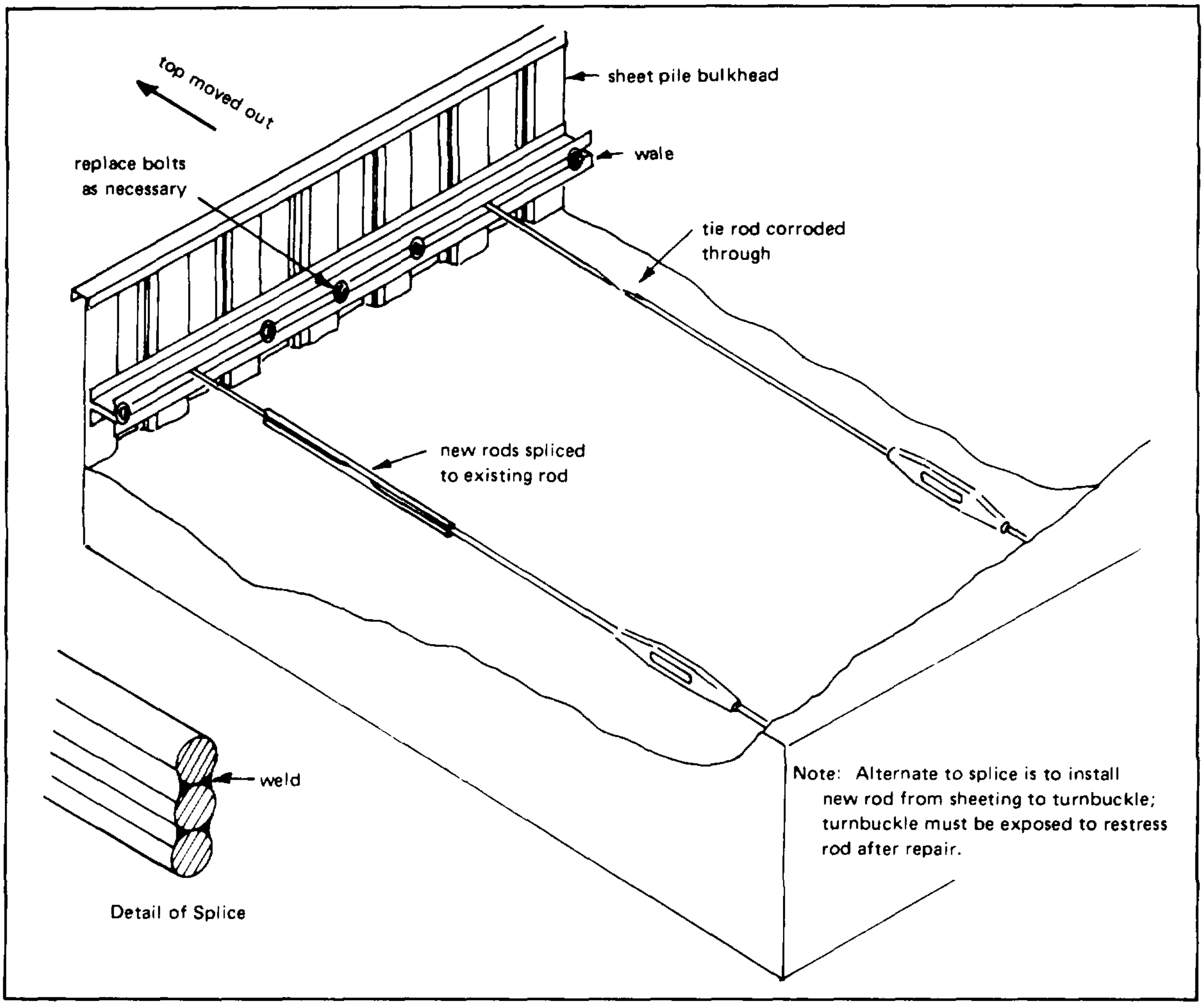

Figure 7-9. Repairing tie rods.

Because of their cylindrical shape they are more easily protected by wraps than are other pilings.

7.6.3 SUPPORTING COMPONENTS. Steel supporting components (wales, braces, etc.) should be repaired or replaced, as necessary. As far as possible, they should be located above the high water line where corrosion is less severe.

7.6.4 UTILITY LINES. The basic objective is to maintain the distribution systems for the utilities as economically as feasible and still be consistent with operating requirements, sound engineering practice, and proper protection to life, health, and property. All necessary repairs should be made as required by the periodic inspection indicated in Table 7-2. These repairs may require replacing items, tightening loose connections, tightening or repacking valve gland and conduit seal glands, or welding defective parts or sections. Paints and coatings should be replaced as indicated in 7.2.2 and 7.2.3. References 7-18 and 7-19 give information for protecting fuel lines under piers. The cathodic protection systems should be maintained in accordance with manufacturer's instructions. In gas distribution systems, leaking pipes are repaired by shutting off gas, tightening connections, and rechecking leaks with soapsuds. When working on electrical power transmission and distribution systems, an assistant must always be available to render assistance or first aid. Extensive replacements of defective systems shall be made in accordance with current criteria for new construction.

7.6.5 MOORING FITTINGS. Maintenance of mooring fittings (bitts, bollards, cleats, chocks, etc.) includes tightening or replacing bolts; replacement of cracked, broken or badly corroded fittings; and reinforcement or replacement of foundations. Boltheads exposed to the atmosphere should be protected from corrosion by potting the bolt holes with poured lead or with an epoxy putty. New fittings should be of cast steel and be at least the same size and capacity as those they replace. They should be painted with coal tar (see 7.2.3).

7.6.6 DRYDOCKS. See Appendix. B for more information on graving docks.

7.6.7 FLOATING STRUCTURES. Repair of holes in the sides of floating structures, such as floatings, lifts, and camels, should be made by welding on steel plates. The plates should be rounded and the welding be as smooth as possible to avoid conditions which accelerate corrosion. Temporary patching can be made by bolting plates over the holes or with epoxy putty if welding of plates would require drydocking. Cathodic protection will protect the underwater steel from corrosion, and protective coatings should be used above water. Because of their resistance to impact and abrasion damage and to corrosion, zinc inorganic coatings (see 7.2.3) are recommended for steel work decks on barges and cranes.